Forecasting Project's evolution. A step forward from the EVMS.

J. Ordieres-Meré, I. Ortíz-Marcos, J.R. Cobo-Benita, A. Uruburu[a,b,*]

ETSII. Universidad Politécnica de Madrid. c/ José Guitérrez Abascal 2, 28006 Madrid

PMQ research group (http://www.upm.es)

Abstract

The goal of this work is to define a framework for project forecasting activities as well as to set up proposals regarding improvement for some of the tools involved in these processes. In particular attention will be payed to Earned Value Management System (EVMS) tool as it is a well known instrument for project monitoring and, in some cases, for project forecasting too. Main innovation in this work is the proposal for estimation SPI and CPI indexes on the next future of the project in accordance to their previous values as well as to the impact in the project of non technical factors like team construction, common vision for the project and other managerial aspects related to it. A new model is provided in this paper allowing to process surveys based information from the project team in order to adjust the estimation for next values of already mentioned EVMS indexes, in order to produce a more consistent forecasting for the project evolution.

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1. Introduction

Project monitoring is a complex task, very dependent on what exactly becomes the interest of the project manager. In fact particular monitoring activities are really depending on type of project management strategy adopted. They depend on CPM, critical chain, extreme programming or any other strategy previously selected for running the project.

The concept of Earned Value began in the 1890's as the early industrial engineers measured performance in American factories. They defined a "cost variance" to relate "earned standards" against "actual expenses" to determine performance. It was only in 1962 that Earned Value was formally introduced on projects by the US Navy, as part of the development of the PERT/Cost methodology. In 1967 the US Department of Defense released its first official list of Cost/ Schedule Control

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Email address: `{j.ordieres,isabel.ortiz,joseramon.cobo,angel.uruburu}@upm.es` (J. Ordieres-Meré, I. Ortíz-Marcos, J.R. Cobo-Benita, A. Uruburu)

Systems Criteria(C/SCSC)Fleming and J.M. [9], signaling the formal initiation of earned value analysis, which still represents management's best chance at measuring a project's progress in an integrated manner. In 1996, a new set of criteria were produced to encourage adoption in the private industry, by making the criteria more 'user friendly'. The National Defense Industrial Association (NDIA) developed these 32 criteria and named it the Earned Value Management System (EVMS) criteria, detailed in the DoD's acquisition policy document DoD Instruction 5000.2R. They are currently embodied in ANSI/EIA 748. Finally, the Project Management Body of Knowledge (PMBOK)ansi and PMI [1], developed by the Project Management Institute, recommends utilizing a similar set of Earned Value criteria, as part of Project Cost and Project Communications Management (Performance Reporting).

The basis of Earned Value are well and comprehensively documented in many public domain sources (Lipke [11],Fleming and J.M. [9], Christensen [5]).

Nowadays, one of the important problems for project management team is accurate estimation time and cost of work completion in a project. EVMS is known method with wide application which is used for project cost and time forecasting in management of a project. Earned Value is a project management technique to measure, at a specific date, the progress and performance of a project against the plan, and to estimate future performance. Earned Value considers three dimensions:

- Planned expenditures. *The budgeted cost for the work scheduled to be completed up to a given point in time. Formerly known as BCWS (Budgeted Cost for Work Scheduled)(PV).*
- Actual expenditures. *The total actual cost incurred in accomplishing work during a given time period. Formerly known as ACWP (Actual Cost for Work Performed)(AC).*
- Budgeted expenditures. *The budgeted amount for the work actually completed during a given time period. Formerly known as BCWP (Budgeted Cost for Work Performed)(EV).*

For actual work accomplished. This provides a superior view into the project state than only looking at the first two dimensions. To facilitate variance analysis a common unit of measure for all of these basic metrics is essential. Historically this has been a unit of "value" or "cost", typically either EUR or hours. From here EVM integrates cost and schedule control under the same framework and indirectly scope, throughout the BCWS concept and its cost baseline. The EVM concept it is supossed to make possible to estimate performance variances and indexes allowing to detect overcosts and delays.

In this paper EVMS will be identified as one of a set of potential tools to be used for project forecasting and some additional tools will be proposed as add-ons for improving its estimations. As a matter of forecasting and considering all the previous factors mentioned before, another potential drawback of EVMS is that indexes are measured always regarding backwards, and it seems a little bit crazy try to predict the future based on indicators showing the past. In addition only hardware is considered into the index-based forecasting models, but some authors support strongly the impact of 'social' factors into project's evolution.

The aim of this paper is to contribute to get improved forecasting available from EVMS by combining classical hardware oriented indexes with more social oriented ones, considering factors like project's common vision into the project team, leadership for the project manager, customer's perception of added value and so on. This will be like some kind of 360º vision, but not about particular people but around the project.

Organization of paper will deal with discussion about what project monitoring means and how EVMS outperforms in that area. Specific section will be devoted to discuss problems and workarounds for EVMS in project monitoring, before going on Project forecasting section, where more detailed analysis will be carried out in terms of what factors need to be managed carefully when this technique is used for project forecasting. Next section will concentrate efforts into the consideration of social factors affecting to projects before to propose particular metrics for these factors and some predictive ways for taking them into account.

2. Project Monitoring Dimensions.

Many works support EVMS as a tool for advanced prediction of final duration of the projectAttarzadeh and Hock [2], Cioffi [7, 6], Lipke [14]. Probably a better approach in practitioner terms will be to consider monitoring activities in a multidimensional path. Under this paradigm, specific tools will be required on each individual dimension.

In any case, and just as an example, lets to accept that classical CPM strategy is in place for managing the project. Here it is possible to identify three complementary and different dimensions for project monitoring.

- First dimension is engaged with "*Critical Path slippage*", because this is what causes legal delay ramifications.
- Second dimension is related to "*Near-Critical Path slippage*", because this is slippage that is so close to the CP that it can easily overtake the CP slippage.
- And third dimension, which is related to "*Non-Critical Path slippage*" which some authors call "*mass volume work*".

Accepted tools for working at first dimension are analyses of the CP at the beginning of the period, identification of any mid-period CP shifts, and identification of the total slippage along with determination of responsibility.

Accepted tools in second dimension are also analyses of the CP looking at any mid-period shift overtaking the CP slippage. Even in this approach there are intrinsic uncertainty because task duration is just an estimation and, in this sense Monte Carlo simulation is a powerful methodology to deal with project uncertainty. After estimating probability distributions of costs and activity durations, the project is simulated for different values of activity costs and durations. It provides the probability distribution of project total cost and schedule. Depending on activity durations and the real evolution of the project, the critical path could be different in different runs of the project. Criticality is the probability of an activity to belong to the critical path. Special effort should be made in order to reduce the duration of activities with high criticality numbers, as we will be decreasing the project total duration (in a probabilistic sense). Williams [24, 23, 22] proposes to complement criticality with a measure of cruciality, that is, the correlation between the duration of an activity and the duration of the total project. Delays in very crucial activities will induce delays in the total project schedule. Williams suggests managers to make efforts to reduce the risk of activities exhibiting higher levels of cruciality.

Accepted tools in third dimension are, among others, EVMS. Earned value metrics have been widely used to monitor the status of a project and forecast the future performance, both in terms of time and cost. The use of the metrics of the project's performance is numerous (see ansi and PMI [1]). The EVMS principles address only the project work scope and EVMS ignores the product scope and product requirements. In order to overcome these effects some other methods were suggested Staley et al. [18], Solomon [17].

3. Problems for EVMS in Project Monitoring.

A successful monitoring work needs to pay attention to all the three dimensions, as just as an example, EVMS provides monitoring of mass volume work Lipke [11], including both critical and non critical activities, so unfortunately other techniques are needed to monitor critical and near-critical activities to prevent delay to the completion date. If work is getting installed close to the planned rate, then the project is more likely to get done without disruption at the end. But, EVMS is not enough because it is possible for a project to focus on all work at the exclusion of the Critical Path work and still show good EV metrics, while seeing project delays.

In addition, EVMS has some severe accuracy problems that must be monitored and accommodated. In the first periods of the project, due to very low values of parameters, there are variations for SPI or CPI quite unbounded and providing not assessed information about performance of the project. During the last periods, the EVMS data is misleading too. Since most of the metrics in EVMS are used as comparisons to the total final budget, Schedule and Cost Variances trend back to 0 as the work near the end of the project, and SPI/CPI trend to 1 in similar situation. So, if it was decided to monitor the SPI/CPI index, it will be almost impossible to know if the project is in trouble in these periods. To overcome this limitation Lipke [11, 12] propose the use of Earned Schedule (ES). ES is claimed to be analogous to EV except that a time or duration based measure of schedule is used instead of cost for measuring schedule performance; i.e. it is used the date when the current earned value should have been achieved.

In this sense EVMS it is not a risk management tool, even when EVMS is a great way to watch the non-critical work and help minimize the risks of stacking of work at the end of the project. In order to improve EVMS results some researchers (Pajares and Lopez [16]) have proposed algorithms overcoming difficulties of EVMS at the end of the project as well as for considering the risk -as variability of task's duration- as a factor into the model itself.

In addition to previous questions and in terms of difficulties, there is an issue regarding a fundamental factor for its calculation, which is expenditures (ACWP). Even on the contractor side, it is very hard to be allowed to see and/or use real job costs in EVMS calculations. Contractors do not want the Owners to see where they are taking a production loss beating so they don't provide real job costs to the scheduling/EV personnel. This aspect in fact makes sense for EVMS when applied to internal projects mainly or when strong systems for spent effort are in place.

All the dimensions mentioned here works in order to produce a "monitored vision" for the project as it was because all the factors considered require to be happen some time ago in order to be considered inside the dimensions. This is not dramatic but it doesn't help the prognosis that a project manager is looking for, instead of that it is a sequence of photographs at different moments of project's past.

Major problems in project monitoring are not mainly related to theoretical issues, even when there are some particular questions to be managed appropriately. If, and only if, the schedule network is very well done, encompassing all the scope of work and accurate sequencing, and it contains careful resource planning, and if locations are taken into account, then monitoring the Critical and Near Critical Paths are the most important because all problems will show up here in time to deal with them. Most common problems come from practical approach during daily development of the project. It happens that most schedules do not have decent resource planning and few schedule around available spaces/locations, and as a result, the Critical Paths may not be accurate. In this case, there is a huge risk that a project may show on-time completion comparing only end date slippage (CP delay), but float dissipation (with inaccurate float values) may allow stacking of both similar trades as well as competing space trades. This will result in disruption and delays when it takes more resources than the contractors expected and when those increased resources hit the job, they will be competing for space to work.

Some authors claim that structural or systemic changes during project life cycle alter the initial expected variability and lead the project outside confidence limits. Moreover some managerial decisions could change some initial conditions. In fact the right approach requires to update project plans in accordance with approved changes. In any case, it is not expected that variances and performance indexes coming from EVM inform about these particular changes or potential cost overruns or delays.

4. Project Forecasting

In a Standish Group study of software projects in both the public and private sectors, nearly 90% of the studied projects failed due to cost and time overruns. In addition, more than 33% were cancelled before they ever came to completion. Nearly one third of the small, medium, and large companies studied experienced cost overruns of 150-200%, with project costs coming in with an average overrun of 189% of the original cost estimate. Likewise, time overruns experienced similar difficulties. Over one third of all the companies in the study reported time overruns of 200-300%, with the average overrun being 222% of the original time estimateChaos [4].

There are another common application for the EVMS to forecast a project's final duration and forecast the future performance, both in terms of time and cost (for an overview, see, e.g.Christensen [5], who reviews different cost forecasting formulas and examines their accuracy). Perhaps one of the most important benefits of earned value is its ability to forecast the final cost and schedule of a project. Some researchers have proposed different extensions to the classic procedures, mainly related to forecasting improvement (Zwikael et al. [26]) evaluate several forecasting methods.

Successful forecasting is based on a foundation of a good baseline plan, tracking performance against that plan, and the commitment of upper management to use and act on the performance data, but right management of these factors is not an absolute guarantee for forecast itself, as it can be derived from section 2, where different dimensions related to project monitoring were introduced. Vandevoorde and Vanhoucke [21] summarize some of the cost and schedule forecasting methods and study their accuracy in real and simulated projects; Lipke et al. [13] have studied confidence limits to improve estimates at completion and Byung-cheol and Reinschmidt [3] have proposed a new probabilistic forecasting method based on Bayesian inference for estimating project performace.

Variations in EVM parameters are expected during project execution, sometimes due to the revision of initially established risk parameters. During project execution, it is possible to use Monte Carlo simulation or any other well know techniques to compute the statistical properties of the pending project. This new information can be used for updating project parameters and to derive variations into the EVM parameters. If the project execution takes place as planned, the project risk should decrease over time, as completed activities have zero risk and thir impact in terms of cost and duration is already known.

Regarding unplanned changes,Williams [24] shows that a high percentage of delays are a consequence of systemic phenomena during specific stages of the project. Usually project manager uses additional resources into special actions in order to reduce delays, but they have an additional negative effect, bringing out more delays and over-costs Williams [25]. Additional effects needs to be considered when subcontractors are affected and they have particular contracts with special protection against these slipages. An interesting way for managing these systemic effects is to apply procedural approach like that supported by maturity models.

It is true that there are some EVMS maturity models in place STRATTON [19], but even when standardization will benefit their parameter estimation, the interest is to have individual vision for the project's future instead of range of variability among projects, at a particular phase of their development.

As established in section 1, the EVMS capabilities used in forecasting estimation are based on performance indexes. All these indexes are calculated by using information coming from the past of the moment where it is used. This is why it is possible to support the concept that EVMS method tries to forecast the project's future based on the past view of the project. If these indexes are independent or function dependent, the forecast will be accurate, but higher variable they are, lower accuracy will be obtained. A key factor regarding the variation for indexes used in the EVMS methodology are closely related to "social" issues, like teamwork, learning capabilities, mental models, decision making strategies and so on inside the project. As in other sciences, it is convenient try to identify these dependencies in a closer way, in such a way it could make possible to improve the forecast evolution of the project.

5. Social factors into the project.

There are many studies regarding classes of teams Katzenbach and Smith [10] ranged from "pseudo teams", "potential teams", "real teams" and "high performance teams" or similar classes as well as the relationship between groups and teams and its importance in terms of project performance. In fact as lower quality into the team as higher probability for having different interests and views about project's target and higher probability of misunderstandings in deliverables, which means reduction in EVMS indexes in the near future.

In fact the wisdom will be to build up a small number of people with complementary skills who are committed to a common purpose, performance goals, and approach for which they hold themselves mutually accountable and, in addition, having members who were deeply committed to one another's personal growth and success. These are fundamentals for a closer vision about the project's goal and for increasing future values of indexes.

A key aspect for project management people is try to grow up their own project team along project development. There are different stages like forming, storming, norming, performing, and adjourning (Tuckman and Jensen [20]), where an equilibrium has to exist between the team's task orientation and it's relationship or team maintenance orientation. Teams oscillate between a focus on achieving their goals and maintaining good working relationships (more the emotional dimension), and they move through stages while dealing with issues that emerge McGourty and DeMeuse [15].

A common way to promote more constructive and productive teamwork is to have the teams create a set of guidelines for the group, sometimes called group norms. Having an agreed-upon, abided by code of cooperation will help groups get started toward working effectively. However, if group members haven't developed the requisite communication, trust, loyalty, organization, leadership, decision- making procedures, and conflict management skills, then the group will very likely struggle or at least not perform up to its potential. One way a team can develop such a code is to create a team charter. Team charters are typically created during a team meeting early in the project life cycle. Involvement of all team members in creating the charter helps build commitment of each to the project and to other members. These team charters are in the heart of teamwork skill improvement.

Other relevant aspect having strong relevance into project performance is the decision making capability. Also, asking a group to invest time and effort in making a decision it is very important that the decision or recommendation of the group be implemented (or very good rationale provided for why it wasn't implemented). There are few things more frustrating than to be asked to spend lots of time and effort on work that goes nowhere. Some of the most interesting work on decision making comes from D. and M. [8]. They propose that decision making can be viewed as an inquiry process rather than as an advocacy process where the concept of decision making is collaborative problem solving rather than a contest.

Reflective analysis supported by this paper is that the evolution of previous factors along the project development are key aspects regarding the evolution of EVMS indexes themselves. Taking into account this effect and the fact that when forecast activities are performed, normally these indexes are used, is why this paper tries to improve the estimation a more dynamic vision of that forecast by making an estimation for the evolution of the indexes in the future, regarding their past evolution and the evolution of previously mentioned social factors into the project. The suggested model is depicted into the next section.

6. Improved Forecast Method based on EVMS indexes.

Some general assumptions need to be performed in order to setup the method. First one is that the project phase were there are an interest in estimating its evolution can be splitted in, at least, three time-sections regarding the amount or type of required effort to be completed. The proposed method will allow to estimate the evolution on the next time-section based on the evolution for the current one. Let's design by i an intermediate time-section, ranged from 1 till N.

Second assumption is related to the existence of a regular time-period for EVMS monitoring activities finer than the time-sections identified, in order to have enough information inside each of these sections. Let's design by j an intermediate period for EVMS project monitoring. These periods are ranged from 1 till M, where M=$\sum_{i=1}^{N} M_i$.

During normal development of the project work is performed and, according to the project management plan, activities for project monitoring at different levels are fired and they involve to the teamwork. At the same time, it is proposed to add an additional survey monitoring the type of team built till the moment, the common vision about the project and its future, the feeling of the personal role inside the team and against the project in terms of customer added value as well as the coherence of the decision making processes carried out during current period by the project management team. Data processing for this survey will measure normalized standard deviation ($\frac{sd}{\bar{x}}$) for questions related to each of previous topics and averaged among topics, in such a way that a project climate index (PrCI) will be produced and stored for this particular moment j.

For all those PrCI produced inside the same time-section till that moment a regression model will be fitted according to the equation (1).

$$PrCI_i(t) = A_i \exp(-k_i t) \qquad \forall i \in [1, N];\ t \in [1, M_i] \tag{1}$$

The meaning of this model is the assumption that project managers will try to foster the skills as well as the common vision for all the team along the project evolution. If this becomes true, it is expected that normalized standard deviation of these questions will be reduced along the time, which means $k_i$factors positive or, by the contrary zero or negative. This will be, in addition, an alternative way to measure the effect of project manager strategy regarding the project team development.

In parallel, EVMS monitoring work have been also performed for current period, so, there are estimated values for SPI and CPI indexes in this period, as well as their variation (??):

$$\begin{cases} \Delta SPI_j = SPI_j - SPI_{j-1} \\ \Delta CPI_j = CPI_j - CPI_{j-1} \end{cases} \qquad \forall j \in [1, M_i] \tag{2}$$

Proposed model estimates EVMS indexes in two steps:

Step 1. Variation of index coefficients for next period:

$$\triangle xPI_{j+1} = \triangle xPI_j * k_i \qquad x \subset \{S, C\} \tag{3}$$

Step 2. Future variation of coefficients during current and next time-section. In order to estimate the evolution of these variations, a linear regression model is proposed. Elements for its construction will be the xPI_{j+1} values already identified for current time-section(3), weigthed according to its position (j+1).

After application of proposed model, there are an estimation for the near future about evolution for EVMS indexes, allowing to predict by means of variable indexes the evolution of the project, instead of make a projection based only on constant valued indexes. This approach benefits for considering inside the forecast the learning capability of the teams, and their speed of learning too.

7. Conclusions.

Current work reviews the complex world of project monitoring and project forecasting, and it shows advantages and drawbacks for the Earned Value Management System. Particular efforts are spent in terms of project forecasting, by explaining soft-factors closed to the project team evolution. These are factors commonly discussed but not so much considered as directly related to the ratio of variation for project development performance.

As main contribution of the paper it is suggested a method for measuring the team-creation process as well as the shared vision about the project evolution, based on a universal survey fired regularly. Under the hypothesis of better team as the project is being developed an logarithmic model is regressed and factors for it are used as main key factors for improving the estimation of SPI and CPI indexes.

Indeed, after developing a model for better estimation of variation of these indexes in the next period, according to previously described social factor model, an estimation for variation of these indexes in the future is also promoted.

With all these elements, it becomes possible to predict future values for SPI and CPI indexes, an then, to use them in order to forecast massive evolution of work performed into the project, as valued for the customer. This approach improves the current solution, only using current indexes as estimators for forecasting, and loosing the perception of team evolution and leadership developed along the project.

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